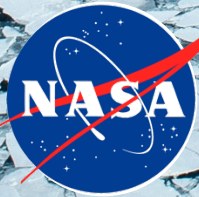


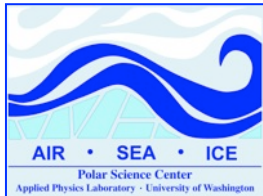
# Expansion and Evolution of the Arctic Ocean Buoy Observing Network

## 5<sup>th</sup> Symposium on the Impacts of an Ice-Diminishing Arctic on Naval & Maritime Operations

Ignatius Rigor, PSC/APL/UW  
Pablo Clemente-Colón, NIC  
and many others







# North Pole Environmental Observatory

## April to October 2010



NOAA Arctic StarDot NetCam #2 Tue Apr 20 16:05:33 2010 UTC  
Exposure: 1/342 Internal Temp: -8.0°C  
Image © NOAA/PMEL

Weather  
Station

Ice Mass  
Balance

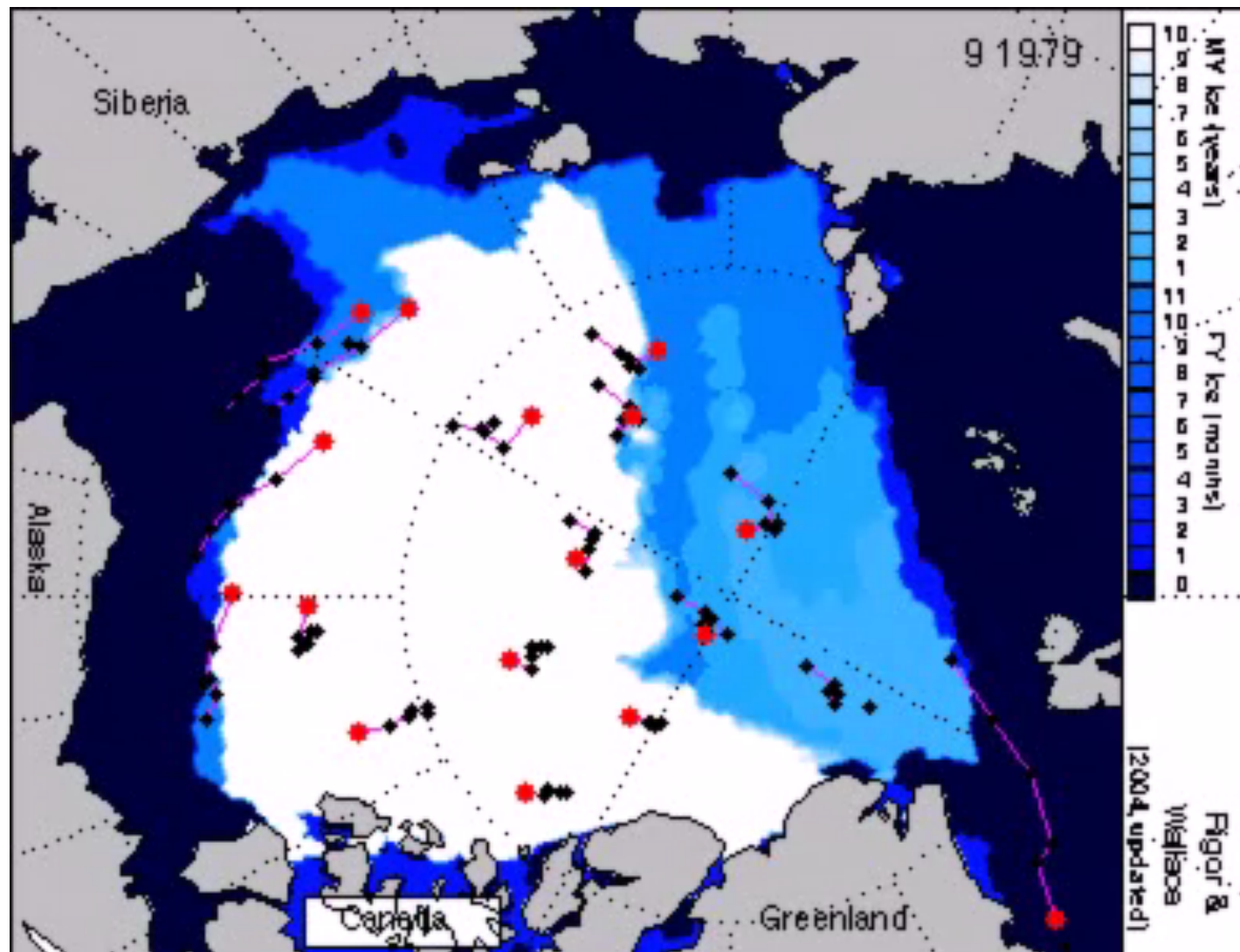
Ocean  
Flux

Ocean  
T & S



Sources: [www.arctic.noaa.gov](http://www.arctic.noaa.gov) & [psc.apl.washington.edu/northpole](http://psc.apl.washington.edu/northpole)

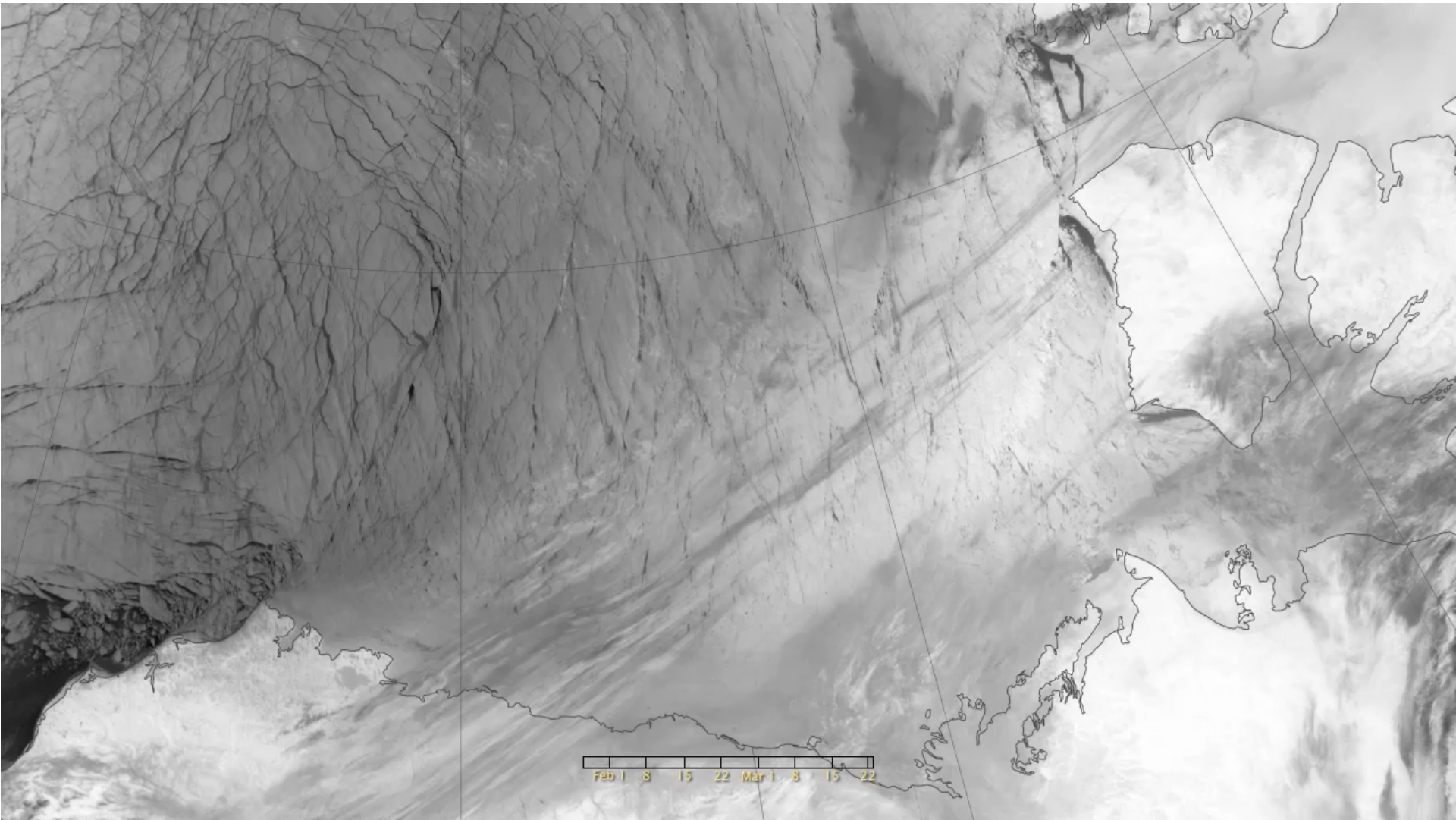
# Retreat of Arctic Sea Ice



- Sea ice grows thicker with age.
- Prior to 1989, ice over 80% of the Arctic Ocean is at least 10 years old.
- High Arctic Oscillation (AO) winds flushed most of the older thicker sea ice out of the Arctic.
- Younger (thinner) Ice persists through today despite “normal” AO conditions.

# Arctic Sea Ice, February – March 2013

## Visible Infrared Imaging Radiometer Suite (VIIRS)

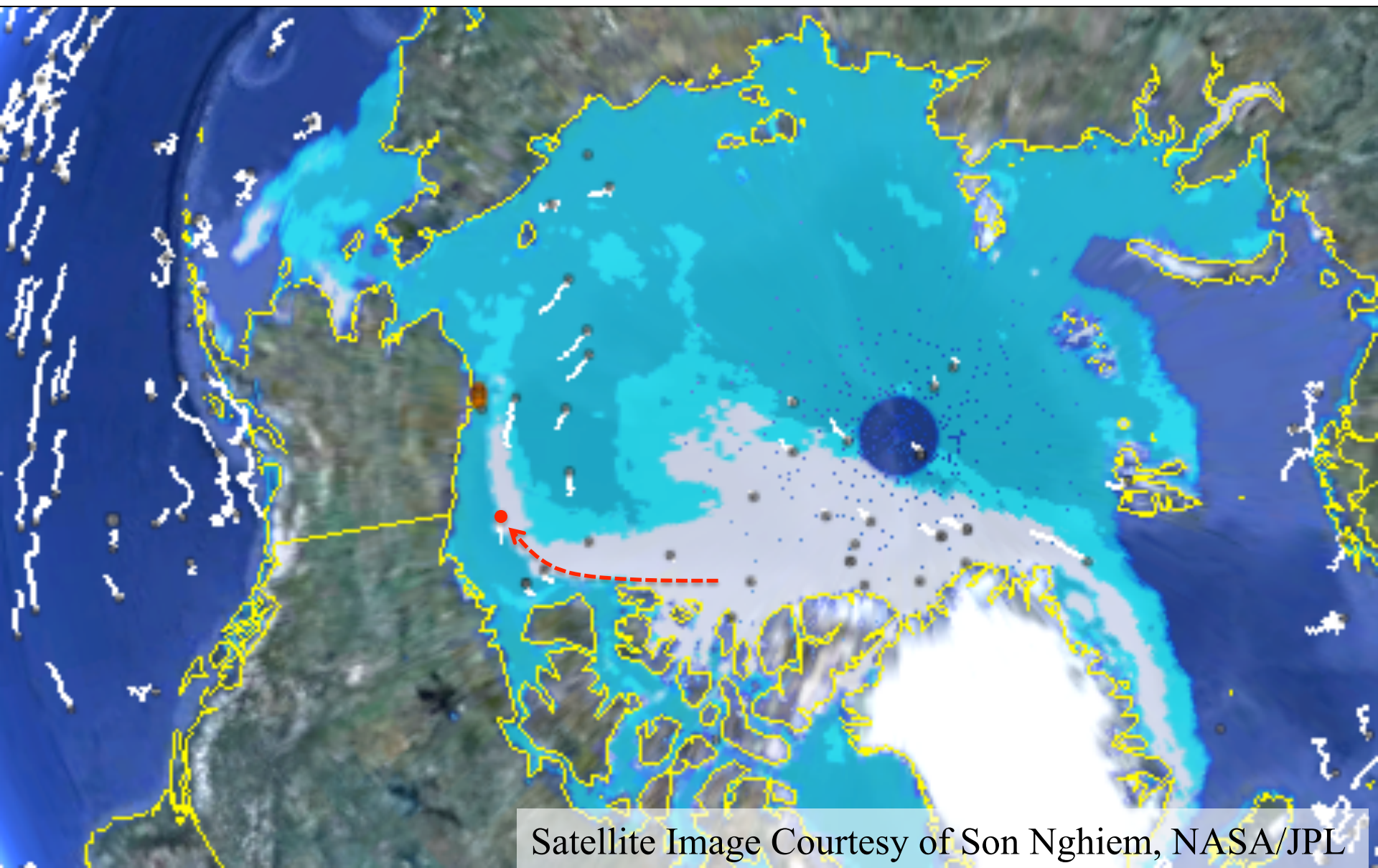


Source: [earthobservatory.nasa.gov](http://earthobservatory.nasa.gov)



# International Arctic Buoy Programme

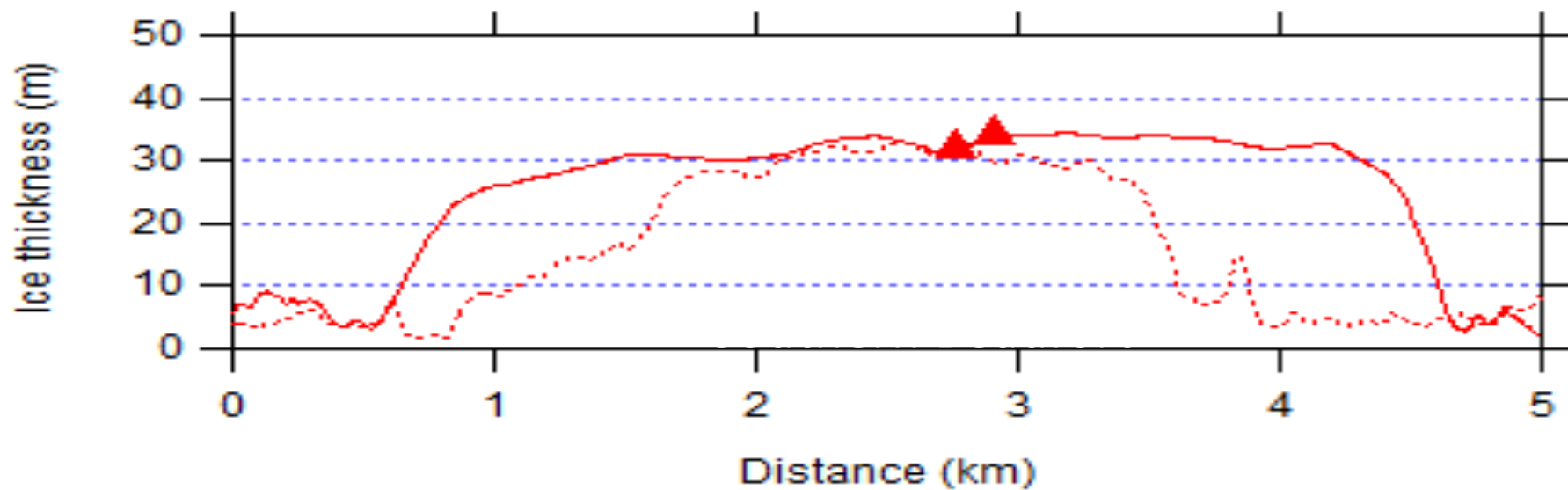
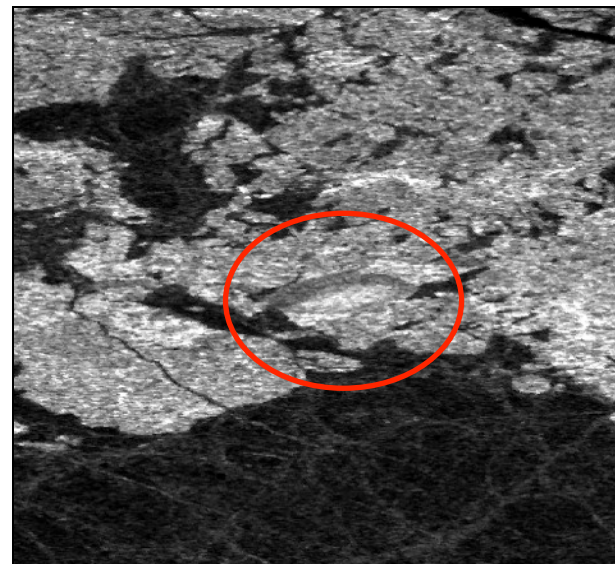
## In Situ Buoys with Oceansat Scatterometer “Ice Type”



Satellite Image Courtesy of Son Nghiem, NASA/JPL



# Ice Islands

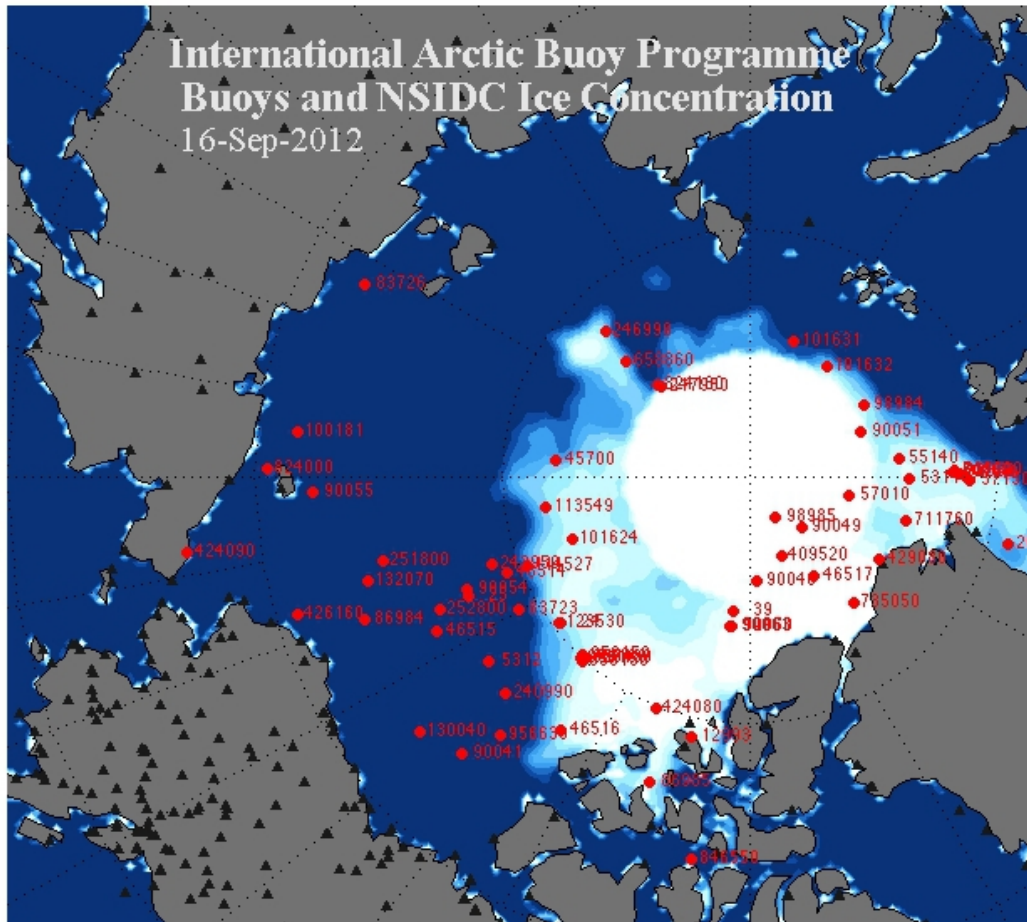


Courtesy of Christian Haas, York U.

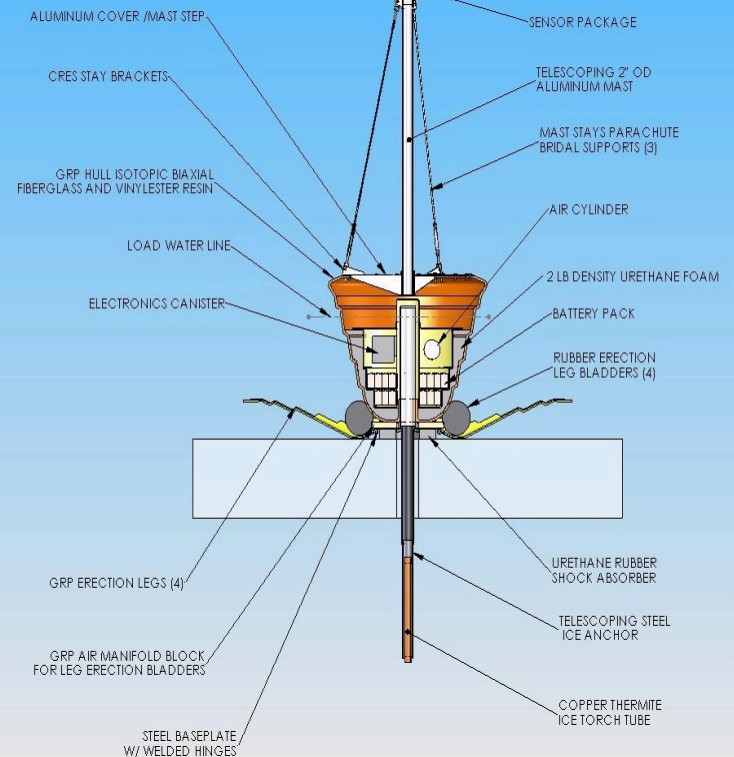


# Arctic Sea Ice Extent Record Minimum

International Arctic Buoy Programme  
Buoys and NSIDC Ice Concentration  
16-Sep-2012



## AXIB Schematic



- Developed by USIABP through a NOAA SBIR.
- Capable of surviving in ice, and open water through freeze/thaw cycles.
- Sensors include air and surface temperature, and surface pressure.



# Coast Guard - Arctic Domain Awareness

## Airborne Expendable Ice Beacon (AXIB)



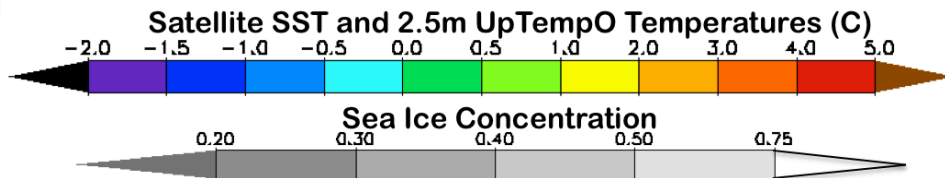
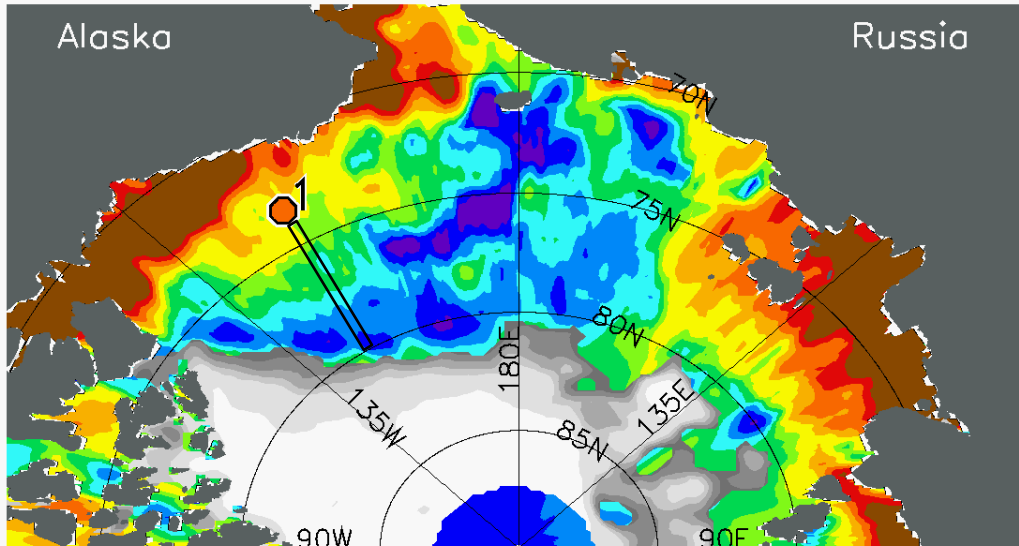
- Developed by USIABP through a NOAA SBIR.
- Capable of surviving in ice, and open water through freeze/thaw cycles.
- Sensors include air and surface temperature, and surface pressure.



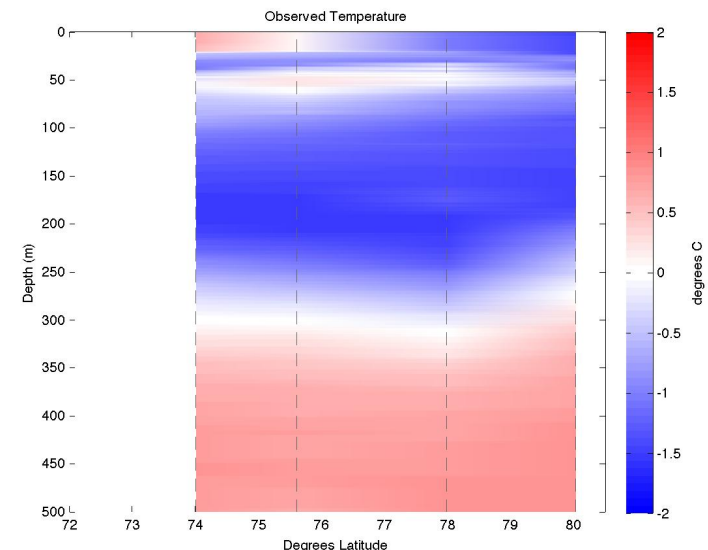
# Coast Guard - Arctic Domain Awareness

## Airborne Expendable Conductivity Temperature Depth (AXCTD)

UpTempO Buoy Positions as of 9/3/2012

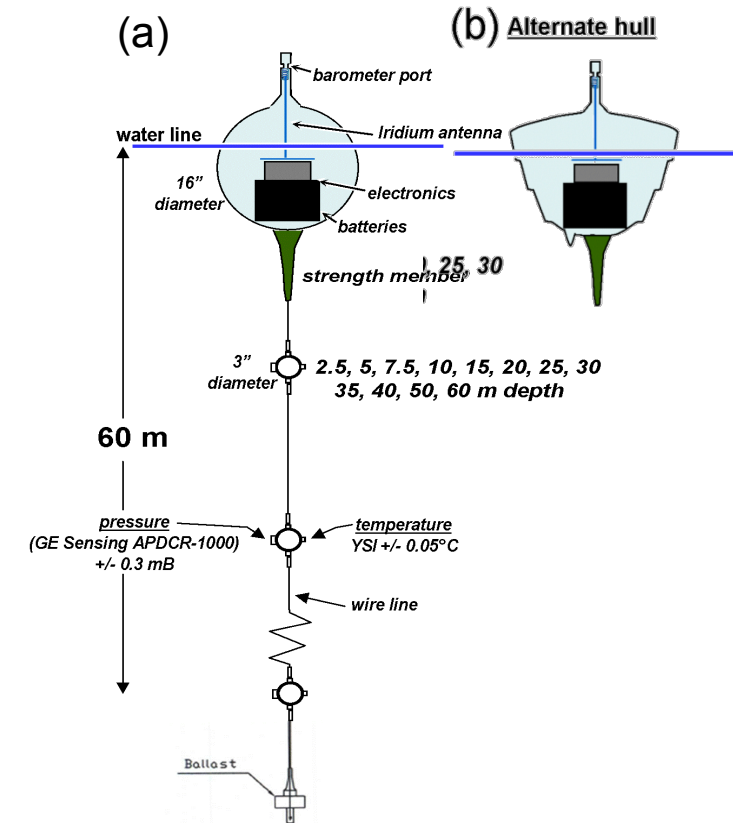
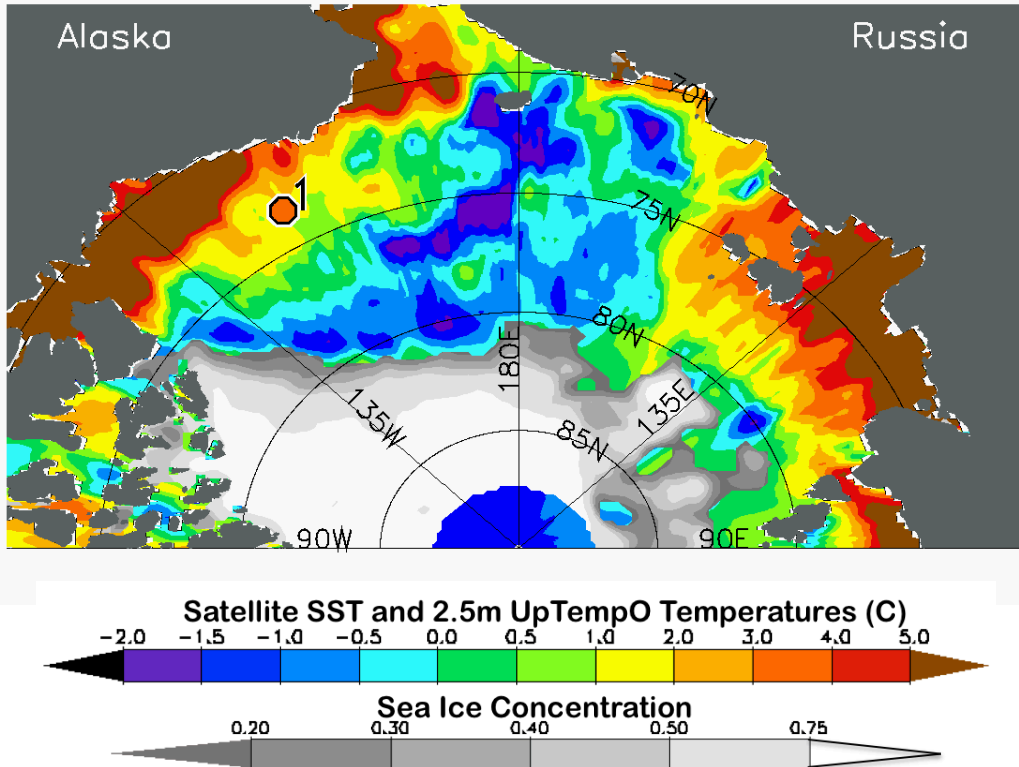


- AXCTDs measure vertical profiles of ocean temperature (heat) and salinity.
- Reynolds SST estimates are warmer than AXCTD measurements.



# Upper layer Temperature of the Ocean (UpTempO) Buoys

UpTempO Buoy Positions as of 9/3/2012



- Reynolds SST estimates are colder than UpTempO measurements.
- Testing UpTempOs produced by Marlin Yug, MetOcean, and Pacific Gyre.



# UpTempO at APLIS 2011

Warmer SST anomalies penetrate down into the Ocean

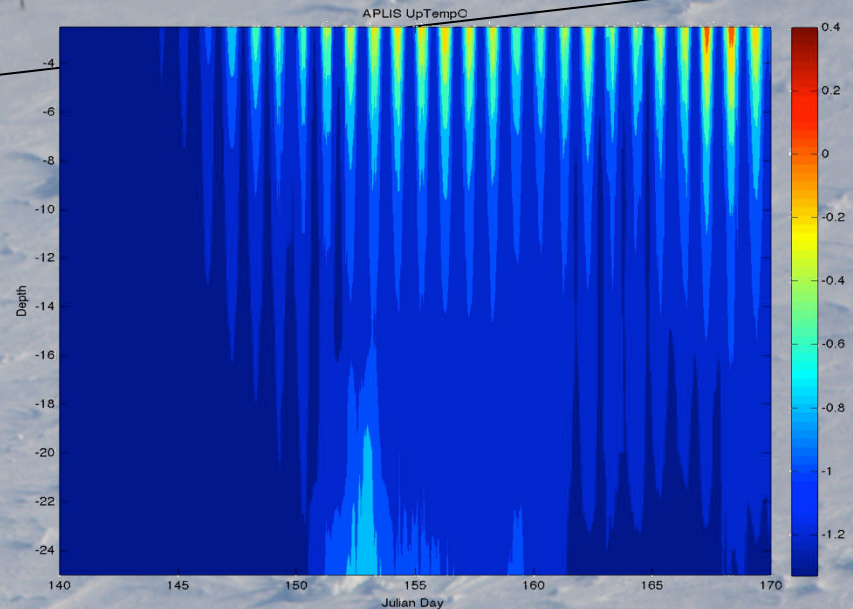
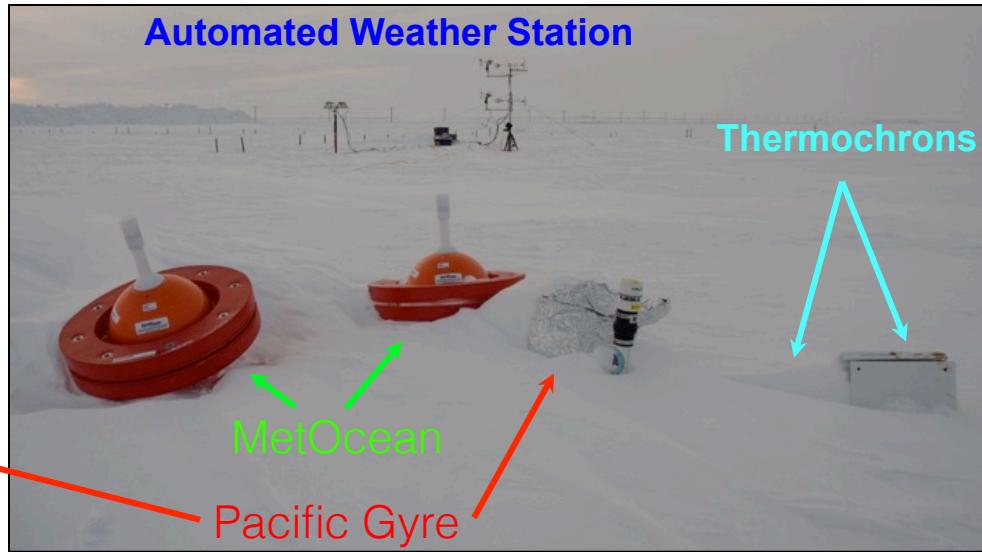
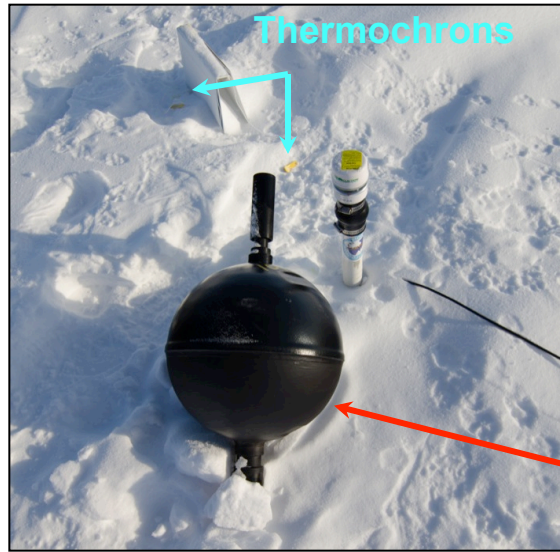
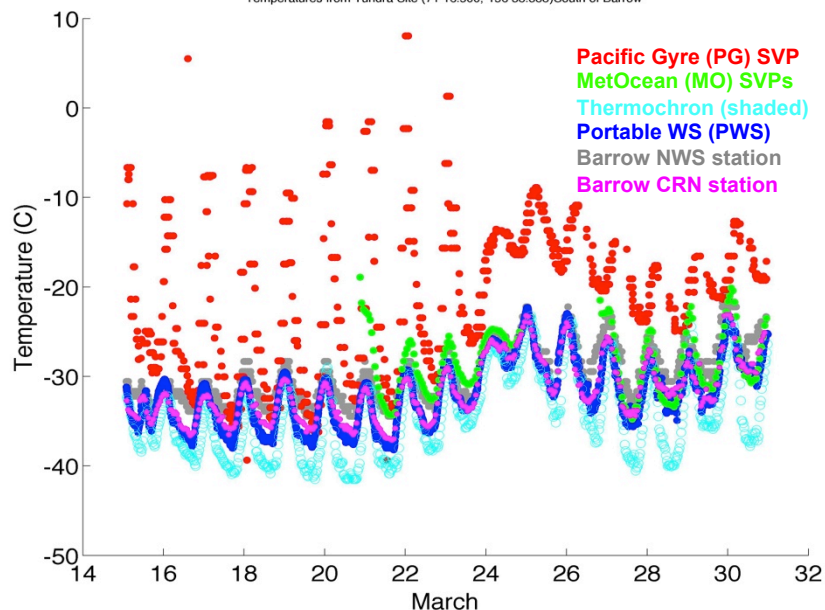


Photo by LCDR John Woods  
from NASA ICEBRIDGE P-3

# NASA BRomide Ozone Mercury Experiment Buoy Test in Barrow, Alaska



Temperatures from Tundra Site (71 16.500,-156 38.388) South of Barrow



- Barrow NWS station 2C warmer than CRN, but matches during foggy days (24-25).
- Pacific Gyre SVP black paint absorbs insolation, and has a warm bias even after shielding.
- Thermochrons: in sun was warmer during day; both biased colder at night.



# International Arctic Buoy Programme

## Arctic Observing Experiment: Sensor Assessment





# International Arctic Buoy Programme

## Arctic Observing Experiment: Sensor Assessment





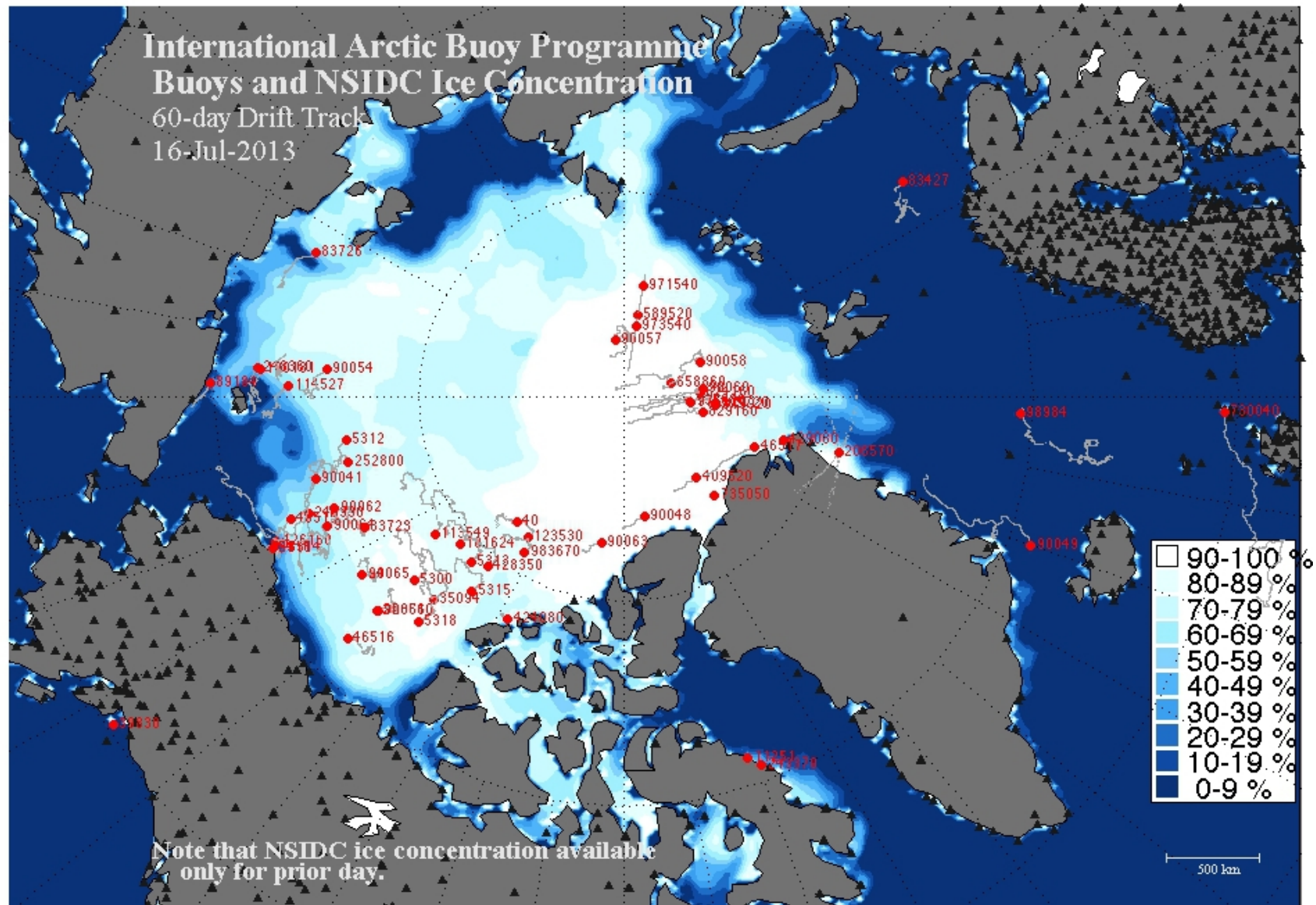
# Arctic Observing Experiment (AOX) Winds, Snow, Sunshine, and Melt

Brw New IOP Cam 2013-05-03 00:00:03



# International Arctic Buoy Programme (IABP)

Arctic Observing Network on July 16, 2013





# IABP Deployment Plans 2013

Polar Area Weather Station



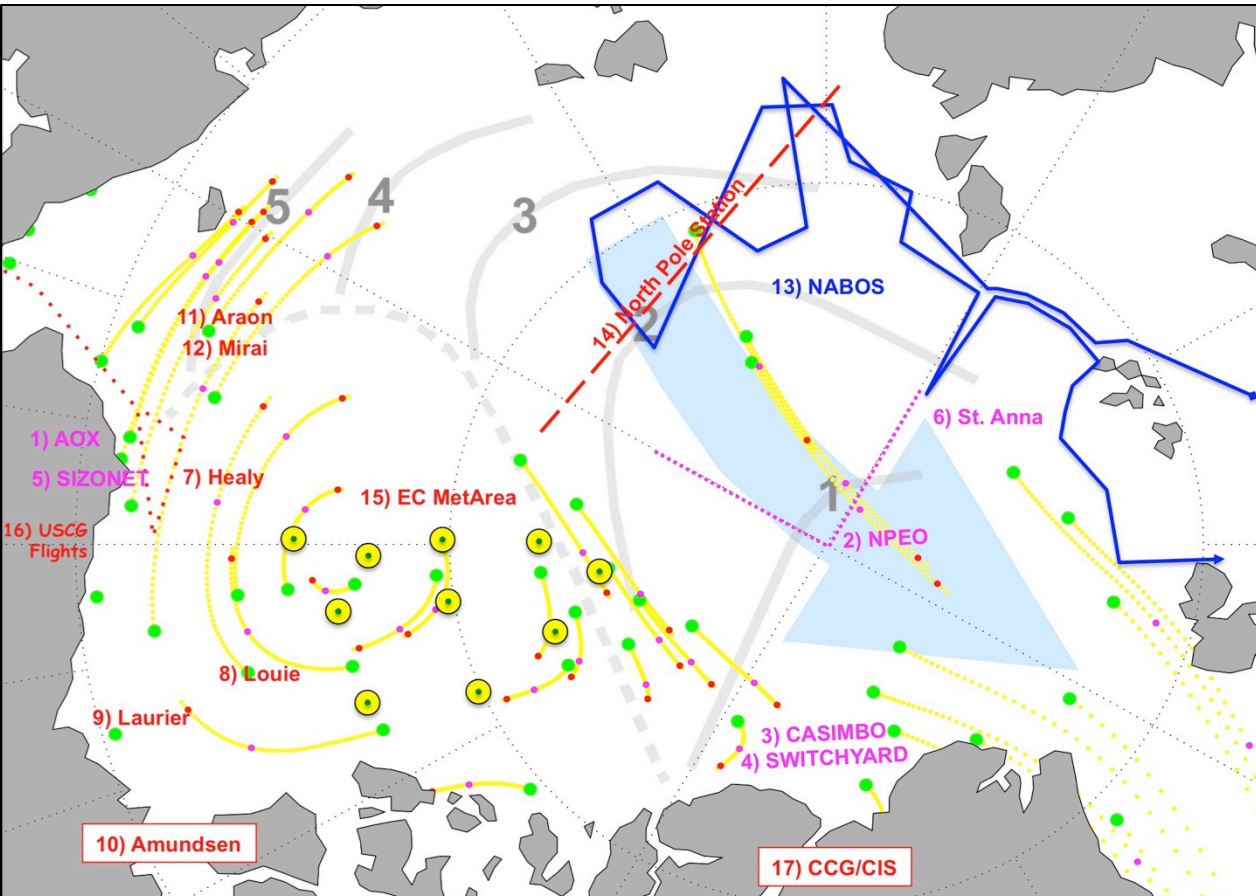
Ice Beacon



Airborne Expendable  
Ice Beacon (AXIB)



SVP / WOCE buoy

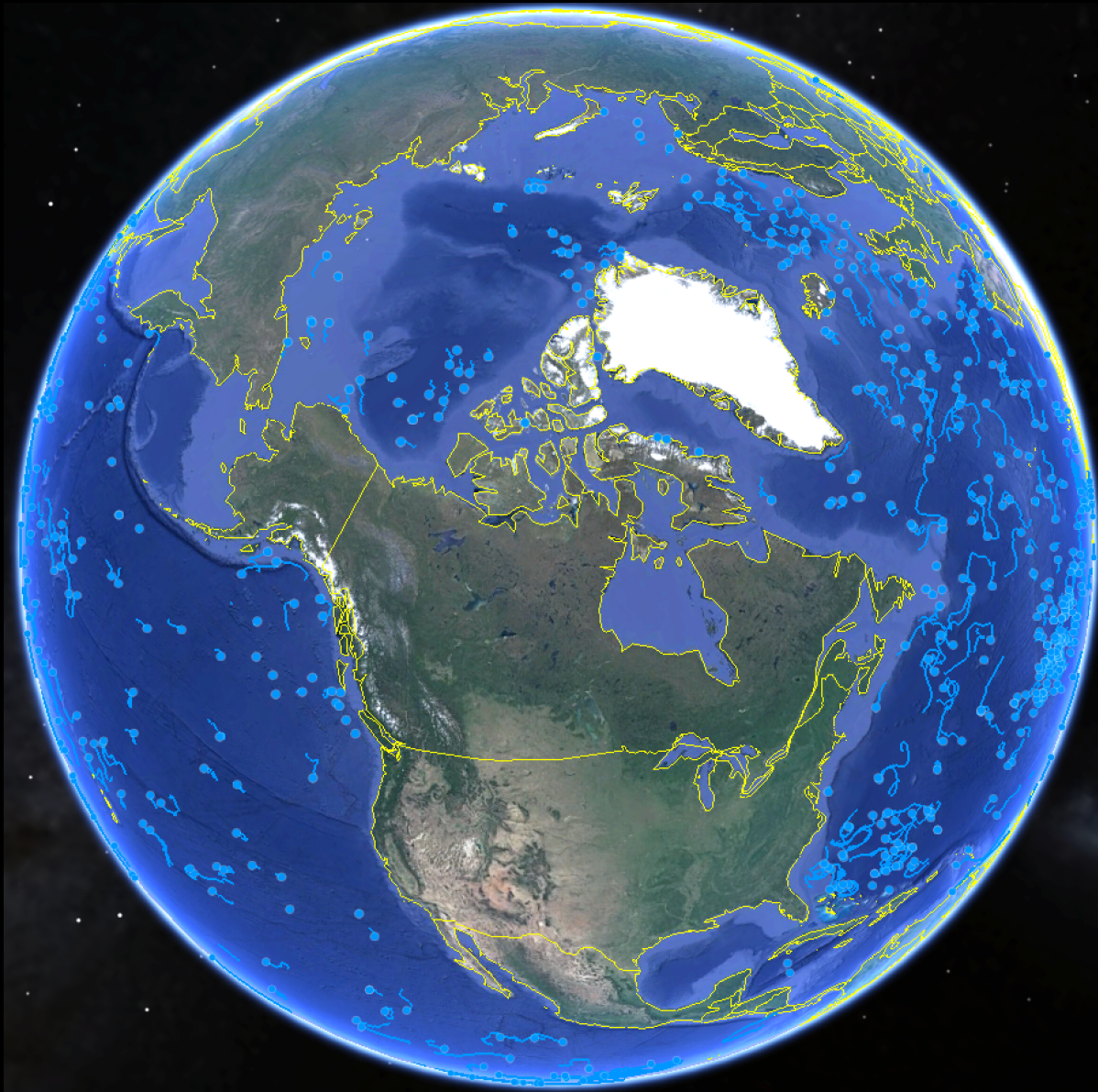


Upper layer Temperature of the  
Ocean (UpTempO) buoy





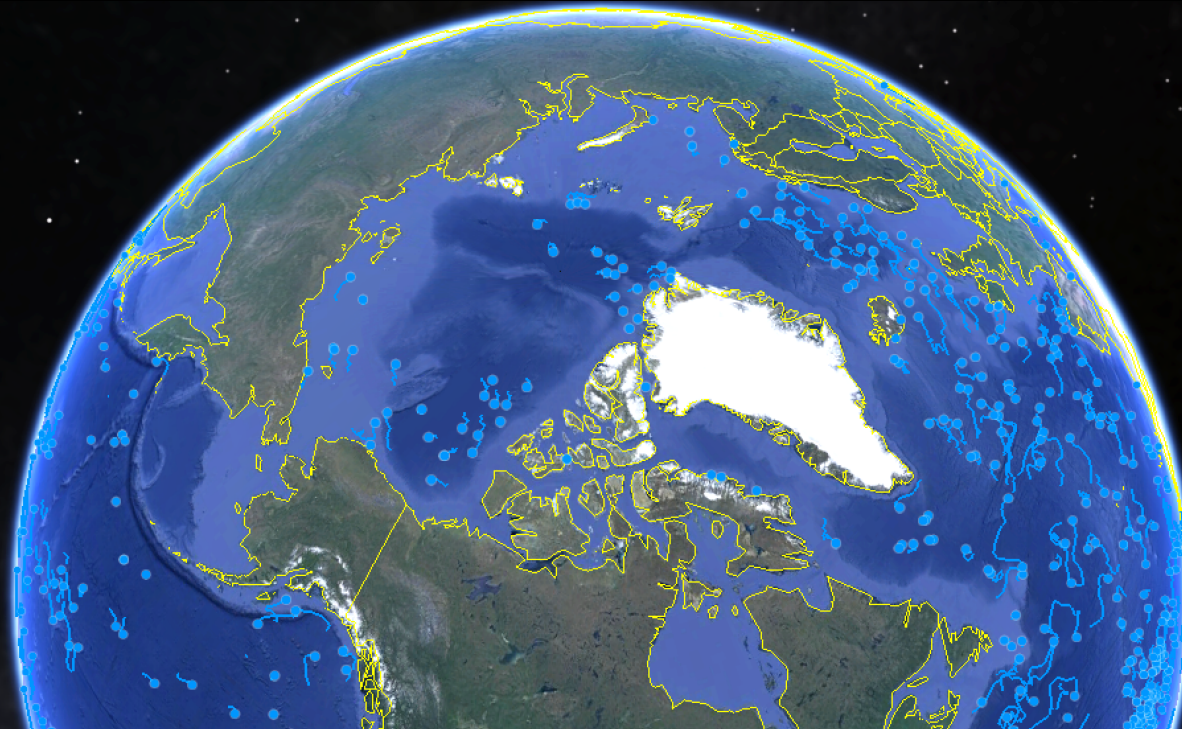
# Observations for Operations and Research WMO/IOC GTS Map – July 2013





# Observations for Operations and Research

## WMO/IOC GTS Map – July 2013



### SUMMARY

- **Interagency and International collaboration has been one of the keys to the success of the IABP/USIABP.**
- **Changes in circulation and the retreat of Arctic sea ice has created challenges for maintaining the Arctic Observing Network. We have responded to these challenges by deploying “cheaper” SVP buoys, developing buoys that can survive in the seasonal ice zone, and have been increasing deployments in the Eurasian Arctic. However, “data voids” in the Eurasian Arctic are a recurring issue.**
- **These in situ observations are critical for our ability to forecast weather and sea ice, ground truth for satellites, assimilation into numerical models (e.g. NCEP/NCAR reanalyses), and for research of climate and climate change.**